Monitoring tropospheric propagation at 24 GHz: A pilot study

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Abstract

HamSCI's upper atmosphere and space physics focus has drawn on ionospheric measurements by radio amateurs using protocols including WSPR, precision measurements of standard frequency transmitters WWV and CHU and systematic information gathering into accessible databases. Such techniques can be adapted to other amateur radio fields to advance understanding of propagation. As an example, we describe a UK pilot system for monitoring tropospheric propagation on 24 GHz. The transmitter (JO01mt22 12 m ASL) on 24.048945 GHz has a GPS disciplined oscillator and outputs 7 W ERP to an omnidirectional slot antenna. Transmissions alternate each minute between WSJT-X's JT4G sub-mode and a carrier with CW identification. A 53 km test path from the GB3PKT beacon over the Thames Estuary glances the sea surface to a receiver (JO01qj81 80 m ASL). At the receiver a masthead down-converter to 400 MHz IF connects to a Raspberry Pi controlled SDR running OpenWebRX [1]. The pilot SDR, an RTL-dongle, is to be replaced by an Airspy R2 [2]. The data monitoring software, based on early WsprDaemon, uses WSJT-X wav files. It logs the basic data of callsign, SNR and frequency from JT4G and signal and noise levels from carrier-only transmissions. SNR derived from carrier measurements shows greater resolution and dynamic range than from JT4G. Measurements of frequency with lower scatter are obtained from cross-correlating the JT4G signal with its sync vector, finding the peaks via continuous wavelet transform, then interpolation. Marine environmental data that may influence propagation is collected from a moored Lightship, including air and sea temperature, relative and absolute humidity and wave height. Rain rate is from a shore station near the transmitter. Radio and environmental data go to a Timescale database with a Grafana dashboard for visualisation.

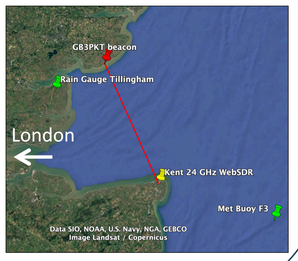
Equipment

Indoor unit

- IF WebSDR at 400 MHz 1 MHz wide using OpenWebRX Software on a Raspberry Pi3B with an RTLSDR at 400 MHz
- Wired LAN connection to site Internet
- Leo Bodnar GPSDO at 123.16667 MHz
- Single coaxial feed to outdoor unit carrying 123.16667 MHz LO plus 400 MHz IF and 12V DC

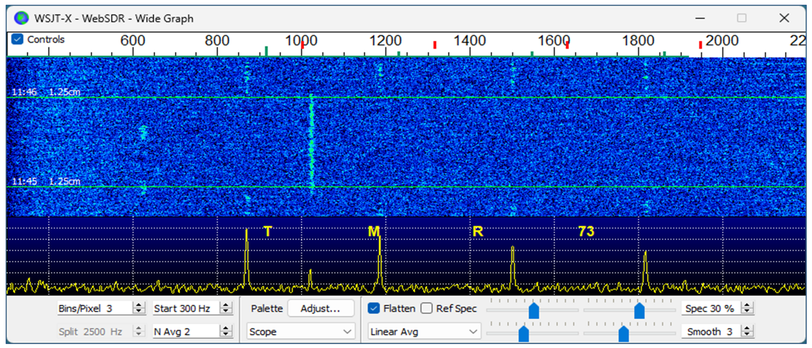
Outdoor 24 GHz Downconverter

- 1.6 dB Waveguide LNA
- OE9PMJ design waveguide image filter
- Commercial waveguide harmonic mixer
- Kuhne 12 GHz Multiplier to 11824 MHz
- 15 dBi 90-degree waveguide sector antenna

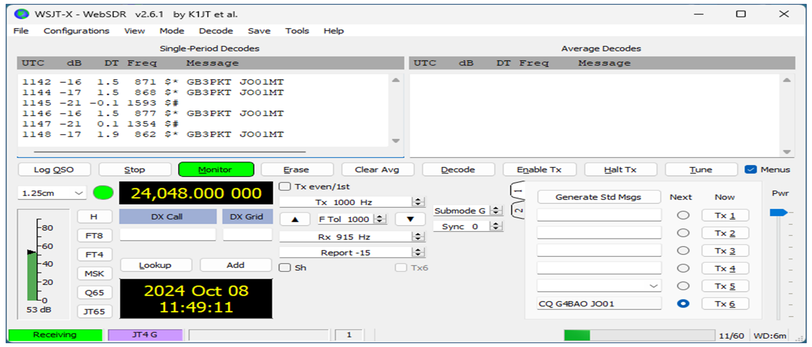


Results

GB3PKT beacon at Clacton was receivable 24/7 over a 53 km sea path.

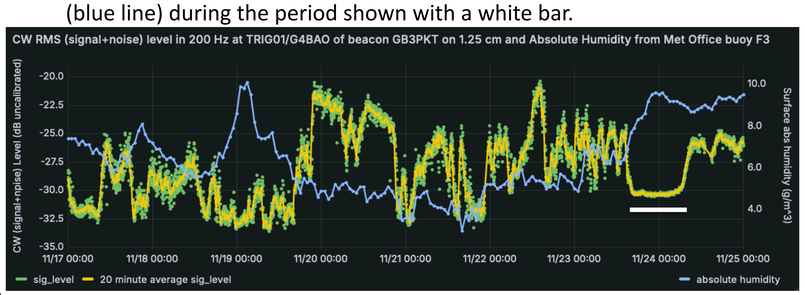


The standard WSJT-X screen allowed us to monitor for RF hardware issues.

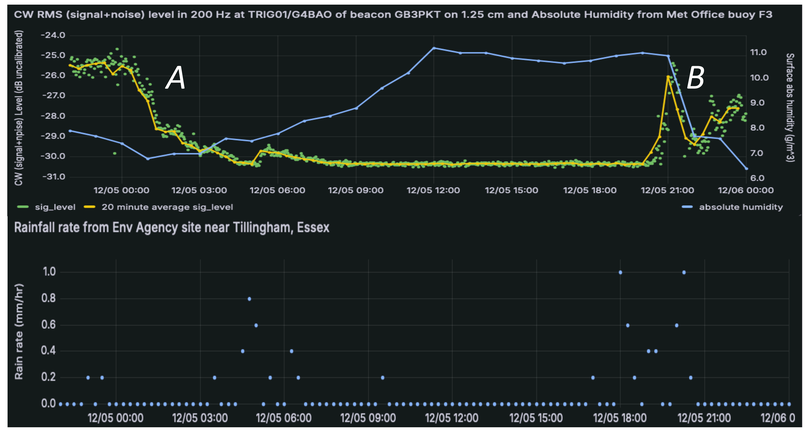


In relation to weather related phenomena, although the distance (48 km) separating environment and radio measurements preclude accurate assessments, encouraging semi-quantitative effects on propagation have been observed. These include:

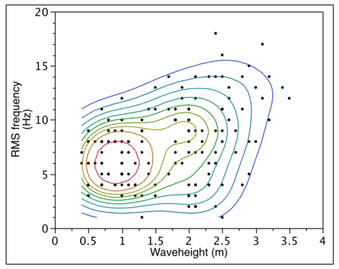
- Signal drop out (Yellow line below) at absolute humidity above 8 g/m³ (blue line) during the period shown with a white bar.


CW RMS (signal+noise) level in 200 Hz at TRIG01/G4BAO of beacon GB3PKT on 1.25 cm and Absolute Humidity from Met Office buoy F3
CW (signal+noise) Level (dB uncalibrated)
Surface abs humidity (g/m^3)
-20.0 -22.5 -25.0 -27.5 -30.0 -32.5 -35.0
10.0 8.0 6.0 4.0
11/17 00:00 11/18 00:00 11/19 00:00 11/20 00:00 11/21 00:00 11/22 00:00 11/23 00:00 11/24 00:00 11/25 00:00
sig_level
20 minute average sig_level
absolute humidity

- Signal level reducing gradually by 8 dB during the passage of a cold front (*A*) followed by a band of rain up to 1 mm/hour and the associated rise in absolute humidity. Signal recovered as absolute humidity fell (*B*).


CW RMS (signal+noise) level in 200 Hz at TRIG01/G4BAO of beacon GB3PKT on 1.25 cm and Absolute Humidity from Met Office buoy F3
CW (signal+noise) Level (dB uncalibrated)
Surface abs humidity (g/m^3)
-24.0 -25.0 -26.0 -27.0 -28.0 -29.0 -30.0 -31.0
11.0 10.0 9.0 8.0 7.0 6.0
A
B
12/05 00:00 12/05 03:00 12/05 06:00 12/05 09:00 12/05 12:00 12/05 15:00 12/05 18:00 12/05 21:00 12/06 00:00
sig_level
20 minute average sig_level
absolute humidity
Rainfall rate from Env Agency site near Tillingham, Essex
Rain rate (mm/hr)
1.0 0.8 0.6 0.4 0.2 0.0
12/05 00:00 12/05 03:00 12/05 06:00 12/05 09:00 12/05 12:00 12/05 15:00 12/05 18:00 12/05 21:00 12/06 0

- Increased standard deviation of the difference between the received and transmitted frequencies with wave height is suggested in the scatterplot at right. The coefficient of regression R^2 of 0.15 implies that 15% of the variance was related to variation in wave height.
- The caveat to this is that the SDR is currently not GPS locked .



Conclusion

24GHz is one of the few areas of amateur propagation investigation still left open to us. Contacts within UK's Ofcom (UK equivalent of the FCC) tell us that they still seem to think there is much to learn about 24 GHz and above. This pilot study shows the feasibility of automatic 24/7 monitoring of 24 GHz Amateur beacons with simple equipment and has thrown up some interesting observations to follow up with the upgraded, GPS locked SDR equipment. Stations living near the coast or at least within the maritime influence, could contribute quite a lot to this research. For example, the effect of offshore wind generators on 24 GHz is worthy of investigation and Nick G4OGI has made a good start on this.

References

[1] OpenWebRX Software Source code at https://github.com/jketterl/openwebrx
[2] Web SDR URL: - http://trig01.ddns.net:8073

Acknowledgements

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